

# Transmaxillary Approach to the Anterior Cavernous Sinus: A Microanatomic Study

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**OBJECTIVE:** Several approaches to expose the anterior cavernous sinus have been used, such as frontotemporal, orbitofrontal, anterior subtemporal, and various transfacial approaches. In an effort to gain exposure to the anterior cavernous sinus without necessitating a craniotomy or wide transfacial exposure, the authors in the present study have developed a transmaxillary approach to the cavernous sinus.

**METHODS:** The approach was developed using data obtained by performing 24 cadaveric dissections. Using a sublabial incision to expose the maxilla, maxillotomy is performed and the course of the infraorbital nerve is identified as a guide to the maxillary branch of the trigeminal nerve. After an osteotomy of the posterior sinus wall and pterygoid plate, the foramen rotundum is identified, which lies a mean of 10 mm from the posterior wall of the maxilla. A superomedial enlargement of the foramen rotundum is then undertaken to ultimately expose the anterior cavernous sinus.

**RESULTS:** This technique offers access to all cavernous cranial nerves, as well as the entire course of the anterior loop of the internal carotid artery to the origin of the ophthalmic artery. With a mean operative range of 38 mm from the posterior wall of the maxilla to the anterior loop of the internal carotid artery, this approach offers adequate exposure with a short operative distance.

**CONCLUSION:** The approach may be useful in limited exposure of tumors of the anterior cavernous sinus and some intracavernous vascular lesions. (Neurosurgery 40:1307-1311, 1997)

Key words: Cavernous sinus, Clivus, Cranial base, Maxillary sinus

Traditionally, surgical access to the region of the cavernous sinus has been accomplished through some variation of frontal, frontotemporal, or subtemporal craniotomy. The various published modifications of these basic approaches enable exposure to specific anatomic regions of the cavernous sinus or the carotid artery and attest to the complexity of the anat-

omy and surgical management of lesions in this area (5-7, 11, 12, 15).

Anterior approaches to the cranial base include transbasal, transnasal-transphenoidal, transoral, combined transmaxillary-transnasal, transcervical, and the invasive midfacial degloving, all of which provide variable access to the clivus (1-3, 5, 8, 13, 14, 17). The transnasal and trans-

oral approaches, although technically straightforward and rapid to perform, offer only limited lateral access and are primarily indicated for exposure to midline pathological findings.

To facilitate more access to the region of the cavernous sinus and middle fossa, the more invasive facial degloving or combined transnasal-transmaxillary approaches can be used. However, for lesions limited to the anterior cavernous sinus, such extensive exposure may not be necessary. Modifications of the Caldwell-Luc maxillotomy approach have been described for management of tumors of the nasal cavity with adjacent cranial base invasion (1, 16). In an effort to avoid a craniotomy, the present study was undertaken. We describe a minimally invasive pure transmaxillary approach to the anterior cavernous sinus, using the course of the infraorbital nerve (terminal branch of V<sub>2</sub>) along the roof of the maxillary antrum as a guide to the foramen rotundum (FR).

## MATERIALS AND METHODS

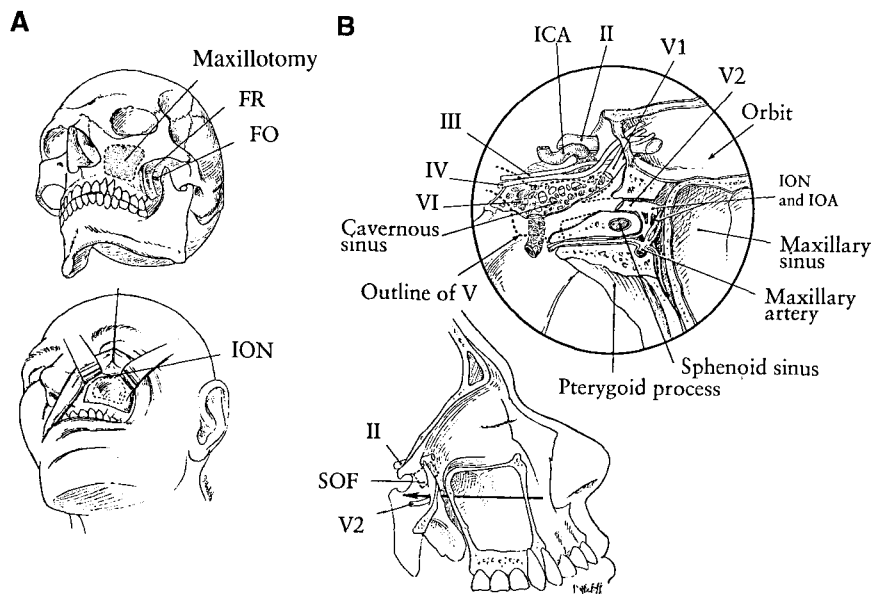
For this study, 24 transmaxillary approaches were performed on 12 injected human cadaver specimens. The operating microscope (Zeiss OPML6; Carl Zeiss, Oberkochen, Germany) was used for all intramaxillary dissections and measurements.

### Surgical approach

A general overview of the approach is depicted in Figure 1. The technique is anatomically divided into three stages: 1) antromaxillary, 2) retroantral, and 3) cavernous.

#### Antromaxillary stage

An initial sublabial incision is made extending from the lateral incisor to the second or third molar, and then dissection of the soft tissue to expose the maxilla up to the level of the infraorbital foramen is performed. The infraorbital nerve and artery are identified, and the neurovascular bundle is reflected superiorly (Fig. 2, upper panel). A small osteotomy is created in the maxilla and enlarged to provide a 2 × 2-cm window



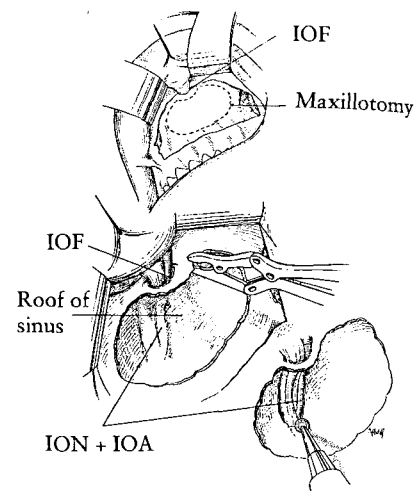
**FIGURE 1.** General overview of the approach. **A**, diagrams illustrating the planned bone removal in performing the maxillotomy (*top*) and the relative position of the FR and foramen ovale (FO). A sublabial incision and then dissection of the soft tissue superiorly to the level of the infraorbital nerve and artery and laterally to the anterior tip of the zygomatic arch is used to expose the maxilla (*bottom*). **B**, sagittal image depicts the transmaxillary trajectory used in this approach. The enlarged diagram (*circled*) demonstrates the details of the trajectory and anatomy encountered through the sphenopalatine fossa. Note the lateral extension of the sphenoid sinus, which may sometimes be encountered with bone removal in the region of the FR. ICA, internal carotid artery; II, optic nerve; III, oculomotor nerve; IV, trochlear nerve; V, outline of trigeminal nerve complex; V<sub>1</sub>, ophthalmic nerve; V<sub>2</sub>, maxillary nerve; VI, abducens nerve; ION, infraorbital nerve; IOA, infraorbital artery. The pterygoid pictured is the medial plate.

into the maxillary sinus, using a rongeur. The frontal process of the maxilla, medial to the infraorbital foramen, is also carefully removed to enable adequate visualization into the maxillary antrum (*Fig. 2, middle panel*). After extenteration of the mucosa in the superior aspect of the sinus, a bulge on the roof of the antrum identifies the location of the infraorbital nerve and artery in their course through the infraorbital canal. At the inferior aspect of the canal, the fine layer of bone covering the neurovascular structures is drilled away using a high-speed drill, exposing the posterolateral course of the nerve (*Fig. 2, lower panel*).

#### Retroantral stage

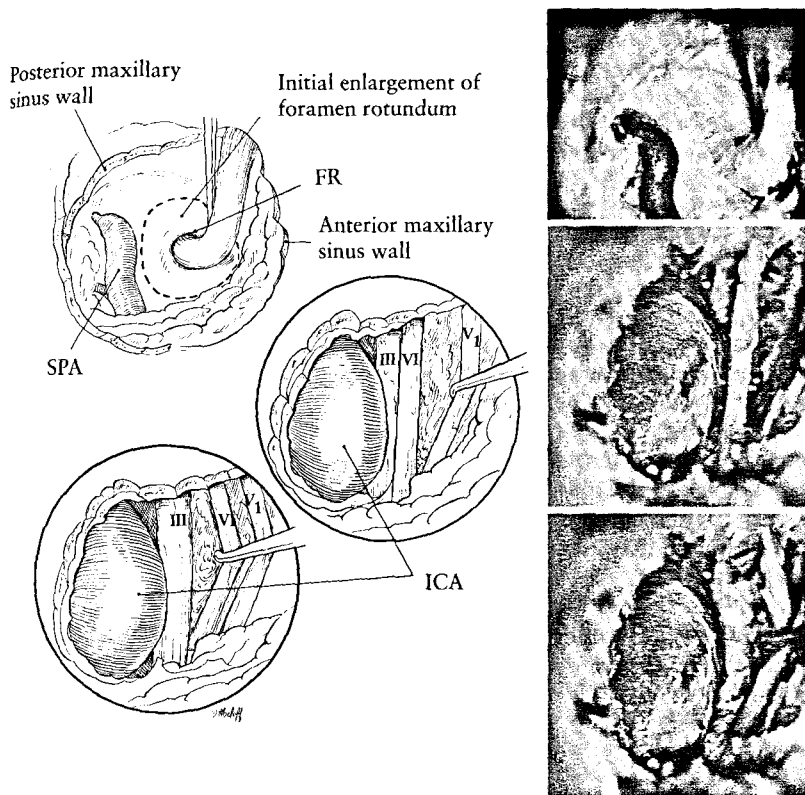
The retroantral (sphenopalatine fossa) space is a fat-filled region traversed by the maxillary nerve (V<sub>2</sub>) and its terminal

branches. The space also contains the serpentine course of the sphenopalatine artery, which represents one of the terminal branches of the maxillary artery. The medial border of the retroantral space is the thin lateral wall of the sphenoid sinus and the pterygoid plate, with the medial pterygoid muscle inserting on its inferior aspect. At this juncture, it is crucial that the infraorbital nerve be identified in the posterior antrum as it enters the infraorbital canal to minimize unnecessary dissection in the richly vascularized retroantral space. Where the nerve enters the canal, a 1.5 × 1.5-cm window is opened using a high-speed drill around the nerve in the posterior wall of the antrum. After removal of the retroantral fat, the entire course of the maxillary nerve exiting the FR on its course toward the infraorbital canal is identified (10 mm) (*Fig. 3, upper panel*). Terminal sensory branches of the



**FIGURE 2.** Antromaxillary stage. Left-sided dissection, surgeons's view. The infraorbital foramen (IOF) is an important landmark identified after a sublabial incision and superior subperiosteal dissection of the anterior wall of the maxilla (*upper*). The maxillary sinus is opened, and the mucosa from the superior wall is removed to reveal the infraorbital nerve and artery, which are identified coursing through the infraorbital canal in the roof of the sinus (*middle*). Removal of the anterior wall of the maxilla down to the superior alveolar ridge enables increased exposure during the deeper phases of the dissection. The infraorbital canal is opened carefully with a high-speed drill to expose the nerve and artery in the canal (*lower*). Removal of the nerve and artery from their investment in the canal will enable later mobilization of these structures laterally in the next stages of the dissection. ION + IOA, infraorbital nerve and infraorbital artery.

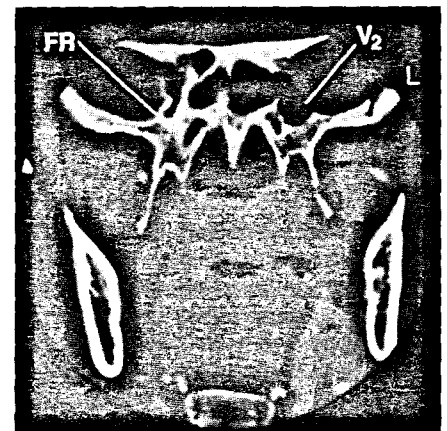
maxillary nerve provide innervation to the posterior molars and can be safely cut without consequence. Perpendicular to the course of the nerve, the main trunk of the maxillary artery is exposed, coursing from the infratemporal fossa toward the sphenopalatine foramen (*Fig. 3, upper panel*). Because of the extensive anastomosis around the nasal cavity by the terminal branches of the maxillary artery, the sphenopalatine artery can be safely ligated distal to the origin of the infraorbital artery to



**FIGURE 3.** Retroantral and cavernous stages. The diagrams are accompanied by correlative photographs of the cadaver dissection. Left-sided dissection, surgeon's view. After a posterior maxillotomy is performed, the retroantral stage of the procedure exposes the contents of the sphenopalatine fossa (*upper*). Medial enlargement of the operating field is accomplished by osteotomy of the pterygoid plate superior to the insertion of the pterygoid muscle. The infraorbital nerve is traced posteriorly past its junction with the posterior superior alveolar nerve to identify the maxillary nerve emerging from the FR. The dotted line indicates the initial superomedial direction of enlargement of the FR to enable access to the cavernous sinus. In the accompanying cadaver dissection photograph, the sphenopalatine artery (SPA) in the foreground is clearly visible and the infraorbital nerve and posterosuperior alveolar nerve have been reflected laterally. To perform the cavernous stage, the FR is drilled posteriorly and enlarged superomedially to the level of the SOF to provide access to the anterior cavernous sinus. The key to proper orientation at this stage of the dissection and to identify the cavernous carotid artery and nerves is to remain medial to the maxillary nerve ( $V_2$ ) and to direct the angle of dissection superiorly. Once the cavernous sinus is entered, dissection is continued medially where the ophthalmic division of the trigeminal nerve ( $V_1$ ) is reflected laterally to visualize the intracavernous carotid artery (anterior loop, internal carotid artery) with the overlying abducens nerve ( $VI$ ) (the view of the oculomotor nerve [ $III$ ] is obscured by the abducens nerve) (*middle*). In the lower diagram and accompanying photograph, the abducens nerve is reflected to clearly visualize the more superiorly located oculomotor nerve ( $III$ ). The SOF is at the superior aspect of the photograph and diagram.

lies only 4 to 5 mm superomedial to the FR; it is imperative that initial drilling toward the SOF be performed judiciously until the SOF is identified to avoid damage to the underlying nerves (initial drilling is outlined in Fig. 3, *upper panel*). Once this is accomplished, more extensive drilling of the thick wall of the bony middle cranial fossa around the FR can be safely performed. The maxillary nerve is exposed in its entirety by drilling the medial wall of the FR along its course (22 mm). The nerve may be unifascicular or may contain as many as 30 fascicles in the area of the FR (10). Care must be exercised when drilling is extended superomedially, because the bone surrounding the SOF is much thinner.

At the completion of the drilling, the anterior cavernous sinus and its neurovascular structures will be identified (Fig. 3, *middle and lower panels*). The anterior loop of the carotid artery will be identified medial to the FR and may be traced distally to the level of the proximal carotid ring or beyond, if desired. The extent of bony removal can be visualized on the postdissection bone window image of the cadaver dissection (Fig. 4). The mean distances and respec-



**FIGURE 4.** Extent of bone removal. Coronal computed tomographic bone window image of a postdissection cadaver specimen demonstrating the extent of bone removal necessary for adequate visualization of the anterior cavernous sinus (left-sided dissection). Comparison is made with the normal contralateral FR. The free maxillary division of the trigeminal nerve ( $V_2$ ) is visualized in the enlarged FR.

enhance access and minimize intraoperative bleeding. Medial enlargement of the operating field is accomplished by extensive osteotomy of the pterygoid plate superior to the insertion of the pterygoid muscle.

#### Cavernous stage

The objective of this stage is to create a window into the anterolateral triangle of the cavernous sinus by transforming the FR and the superior orbital fissure (SOF) into a single foramen. The SOF

tive standard deviations obtained from the cadaver dissections for important landmarks used in the execution of this approach are listed in *Table 1*.

## DISCUSSION

Despite the wide variety of surgical approaches described to gain access to the cavernous sinus, most of these are of an invasive nature, ranging from a standard frontotemporal craniotomy to a midfacial degloving procedure (5, 7, 8, 13–15, 17). In the present report, a less invasive extradural approach to the anterior cavernous sinus is described. The transmaxillary route described in this anatomic study offers direct access to this region, within a short operative range. This advantage has been noted previously by other authors, because a radical pterygomaxillary approach (4) or an extended maxillotomy (8) have been used to gain access to the clivus. The approach in the present report, however, differs from previously published studies in that it uses a pure transmaxillary route for access to the cavernous sinus, which does not entail facial degloving, facial osteotomies, or splitting of the palate. The anterior venous trabecular channels of the cavernous sinus are located a mean of 32 mm from the posterior wall of the maxilla, and access to the anterior cavernous sinus and the anterior loop of the internal carotid artery is possible without retraction. Using the infraorbital nerve as a guide to the maxillary division of the trigeminal nerve, and subsequently the FR, offers an easy and clearly demarcated route to the cavernous sinus that avoids any vital vascular and neural structures until the cavernous stage of the dissection. During that stage, the

window created by the enlargement of the FR allows clear identification of the third and sixth nerves and the first and second divisions of the trigeminal (fifth) nerve.

The recently reported study by Fraioli et al. (6) advocates using a combined transmaxillophenoidal approach for access to the medial cavernous sinus for resection of invasive pituitary adenomas. In their technique, the authors use a transnasal approach to the sphenoid sinus combined with lateral dislocation of the medial wall of the maxillary sinus to widen the operative field and then an osteotomy of the posterolateral wall of the sphenoid sinus to expose the cavernous sinus. The essential difference between this inferomedial approach to the cavernous sinus and the primary transmaxillary approach that we propose is the direction of dissection toward the target region; the transmaxillophenoidal approach uses an inferomedial exposure gained through the transnasal exposure rather than a primary inferolateral exposure to the cavernous sinus through the maxillary sinus proper. The bony enlargement of the FR enables direct and early exposure of the anterior loop of the carotid artery, which underlies the thin posterolateral wall of the sphenoid sinus. If necessary, full exposure of the anterior loop of the carotid artery will require resection of the posterolateral sphenoid sinus wall but lateral exposure to the anterior loop will be obtained in most cases without violation of the sphenoid sinus wall (*Fig. 3*). However, the pneumatization of the sphenoid sinus is variable and a diverticulum of the sphenoid sinus may extend laterally below the optic canal to surround the carotid artery by air cells (9); this can be anticipated by careful review

of preoperative computed tomographic scans or magnetic resonance images.

Potential limitations of the transmaxillary approach include the mucosal dissection necessary from the roof and posterior wall of the maxillary sinus and the potential for inadvertent injury to the sphenopalatine artery before ligation. The extent of bony removal may be tailored to facilitate access to the individual lesion to be addressed. The exposure to the region is somewhat limited but may be suitable for biopsy or resection of small lesions in this location.

In summary, the transmaxillary approach provides an entirely extradural approach to the cavernous sinus. The technique combines the benefits of a cosmetically acceptable approach with a safe trajectory to access limited pathological processes of the anterior cavernous sinus. The approach may also offer versatility to be used with other approaches, such as a midface degloving procedure, for the management of more extensive lesions of the middle cranial fossa.

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**TABLE 1. Measurements between Key Structures in the Transmaxillary Approach to the Cavernous Sinus<sup>a</sup>**

	Average Distance (mm)	Standard Deviation (mm)
Posterior wall of MS → FR	10	0.71
Posterior wall of MS → VTC	32	2.12
Length of SPA	24	2.83
Course of FR	22	1.97
GG → medial loop of ICA	8	0.50

<sup>a</sup> MS, maxillary sinus; FR, foramen rotundum; VTC, venous trabecular channels; SPA, sphenopalatine artery; GG, gasserian ganglion; ICA, internal carotid artery.

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## COMMENTS

This article presents an additional approach to the parasellar space from the front and from below. The steps of the microsurgical dissection are well documented by appropriate drawings.

The transmaxillary approach to the anterior part of the parasellar space, as presented, will provide an excellent approach for the biopsy of a tumorous lesion or a partial removal of the tumor. It is thought that this approach alone, and/or in combination with other approaches, will further extend the possibility for surgical treatment of tumorous lesions of the splanchnocranium extending partially into the parasellar region(s).

**Vinko V. Dolenc**  
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This is a careful microanatomic study of an extradural cranial base approach to the cavernous sinus through the maxillary sinus, which avoids craniotomy and brain retraction. The approach is well described, and the drawings are comprehensive. High-quality photomicrographs of anatomic dissections in this region are usually difficult to obtain.

I have had the opportunity to use the same transmaxillary approach the authors describe in a woman with a trigeminal schwannoma affecting the V<sub>2</sub>, which extended from the cavernous sinus up to the intramaxillary sinus. I achieved a complete tumor resection in that case by performing a sublabial maxillotomy and following the tumorous V<sub>2</sub> up to the cavernous sinus. After complete tumor resection, the bone flap was replaced to maxillary sinus and fixed with miniplates. The outcome was excellent. Although the sublabial transmaxillary approach provides only a limited view of the cavernous sinus and the described relationships of normal anatomy do not directly reflect the pathological picture with which the surgeon is confronted, I agree with the authors that the transmaxillary route is a useful addition to the present approaches to the anterior portion of the cavernous sinus.

**Madjid Samii**  
Hannover, Germany

Couldwell et al. describe a transmaxillary approach to the anterior cavernous sinus. To evaluate this approach, we repeated the dissections according to the authors' steps in our laboratory. The dissections were performed on cadavers injected with colored silicone. After the transmaxillary exposure, we also performed a frontotemporal and orbitozygomatic approach and dissection of the entire cavernous sinus to compare the exposures provided and to confirm the anatomic structures exposed by the transmaxillary approach.

The transmaxillary approach provided a very narrow and deep window to the anteroinferior venous space of the

cavernous sinus and, after removal of the veins, to the inferior aspect of the anterior bend of the intracavernous internal carotid artery. Significant venous bleeding can occur from the venous plexus and may be controlled by packing with Gelfoam or Surgicel. However, this might further obscure the views of the deeper structures and the surgeon might not have proximal or distal control of the internal carotid artery (although proximal control can be obtained in the neck).

The authors state that this approach "allows clear identification of third and sixth nerves and the first and second divisions of the trigeminal (fifth) nerve." We were able to observe the abducens nerve lateral and slightly inferior to the carotid artery. The first division of the trigeminal nerve was observed superior and lateral to the sixth nerve. However, identification of the IIIrd and IVth cranial nerves was much more difficult and required the mobilization of the VIth and Vth cranial nerves. We think that the authors have mislabeled the VIth and IVth cranial nerves.

On the basis of our dissections and experience with the facial translocation approach (which provides a much wider exposure), we think that the exposure provided by the transmaxillary approach to intracavernous neoplasms and vascular lesions is inadequate, deep, and narrow. However, biopsy of appropriately placed lesions will be possible. Additionally, tumors that extend into the cavernous sinus from the infratemporal space and are well demarcated (such as juvenile nasopharyngeal angiofibroma) may be removable by this approach, as may some pituitary and other tumors that extend medially into the sphenoid sinus and cavernous sinus. Extended transsphenoidal approaches with medial maxillotomy have been used for the removal of tumors. The anatomy presented by these authors will also improve our understanding of the exposure provided by such approaches.

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